The Effect Evaluating System of VMS Information Guidance on Urban Road Network

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Abstract. With the VMS gradually extensively used in major cities, it is necessary to evaluate its guiding result scientifically and systematically. This paper studies on the effect evaluating system of VMS, mainly includes evaluation index and comprehensive evaluation two parts. First, the evaluation index is made up of five indexes which are network, economy, environment, safety and driver. Second, compare the common comprehensive evaluation method and the Grey relational analysis is finally chose. Finally, take one region network of Beijing as an example to apply the evaluation system and prove its efficiency.

Keywords: VMS (Variable Message Signs), Guiding Result, Evaluation Index, Comprehensive Evaluation.

1 Introduction

As a part of the Intelligent Transport System (ITS), the real time condition of the upcoming roads is provided to divers using VMS, to help them choose the appropriate route and get rid of the congested road sections or where traffic incidents occur, so as to balance the traffic flows over the network and enhance the utility of it. Since VMS has been widely built up and utilized in big cities over the country, it is becoming necessary to evaluate the guiding result in a scientific way comprehensively.

Hongyun Yao (2005) presented the framework of index system for VMS evaluation, including internal physical evaluation and operation evaluation [1]. Baofeng Sun (2005) evaluated the effect of highway VMS projects on social economy, giving out the appraisal of VMS's guiding result from the point of benefit [2]. Hui Zhang (2009) compared the condition of before and after building up VMS from economic benefits, traffic benefits and social benefits [3]. Srinivas Peeta(2000) evaluated the Advanced Information Systems' effect, which include fluency, safety and air quality[4]. Although the research on VMS's guiding result is carried out for a few years, the evaluation system has not been formed.

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2 Build Up the Evaluation Index System

2.1 Principle for Building Up the Evaluation Index System

In order to establish a scientific and complete index system, this paper obeys the following principles:

(1) Scientificalness. Every index should scientifically reflect the guiding result.
(2) Globality. The indexes should reflect VMS's guiding result roundly.
(3) Operability. The evaluation indexes' data should be collected easily.
(4) Independence. Each index should be independent and make sure no an index belong to its same level index.

2.2 Process of Building Up Evaluation Index

According to the above principles, the evaluation index system, which is showed by Table 1, is built up. It contains five first-class indexes and each first-class index is made up of second-class indexes. In order to describe the following equations conveniently, some rules will be made as follows:

I represents the total number of the road section; α_i represents the section i's weight, $\alpha_i = L_i / L$, in where, L_i represents the length of section i, L represents the total length of the whole road network. Q_i represents the traffic volume, V_i represents the space mean speed, C_D represents the design traffic capacity.

Table 1. The evaluation index system of VMS's guiding result on urban road network

VMS's Guiding Result on Urban Road Network	
First-Class Index	Second-Class Index
Network	V/C Ratio Average Speed
Economic	Time Saving Fule Consumption
Environment	Noise Pollution Exhaust Emission (Include CO, HC, NO)
Safety	Mortality Rate per Million Vehicle Kilometer Ponderance Index of Accident Mortality Rate per Ten Thousand Vehicles Equivalent Accident Number per Ten Thousand Vehicles Injuries and Deaths Ratio
Driver	VMS Utilization Ratio Drivers' Anxiety

Network. Network index includes V/C Ratio and Average Speed.

V/C Ratio. V/C Ratio is an index can reflect the road congestion, the equation to calculate it is showed as follows:

$$\mu_1 = \sum_{i=1}^{I} \alpha_i \times Q_i / C_D \tag{1}$$

Road Network's Average Speed. Road Network's Average Speed can also reflect the VMS's guiding result. The equation to calculate it is showed as follows:

$$\mu_2 = \sum_{i=1}^{I} \alpha_i \times V_i \tag{2}$$

Economic. Economic index includes Time Saving and Fule Consumption.

Time Saving. The network's time benefit is used to evaluate the value of drivers' time loss on road network, which evaluates the VMS's guiding result from the point of view of the economy. The calculation process is as follows:

Value of drivers' time loss on road network (B_{time}):

$$B_{time} = \sum_{i=1}^{I} Q_i \times \frac{L_i}{V_i} \times vot \tag{3}$$

vot represents unit time value (Unit: Yuan/Hour).

Fule Consumption. In the actual road traffic condition, drivers can avoid taking the congestion road under the VMS's guiding, which can avoid the vehicles moving hardly and reduce the fule consumption. Thus, fule consumption is an important index reflects the VMS's guiding result. The detailed calculation process is as follows:

Firstly, use the second steady fule consumption model, which is proposed by Post.etc, to calculate each section's fule consumption.

In unit time, section i 's fule consumption function (F_i):

$$F_i = L_i \times Q_i \times (a + b \times V_i + c \times V_i^2) \tag{4}$$

In where, a =170 $\frac{ml}{km}$, b =-4.55 $\frac{ml \cdot h}{km^2}$, c =0.049 $\frac{ml \cdot h^2}{km^3}$.

In unit time, the road network's fule consumption function (B_{Flue}):

$$B_{Flue} = \sum_{i=1}^{I} F_i \times P_{Flue} \tag{5}$$

In where, P_{Flue} represents the current fule price (Unit: Yuan/Liters) .

Environment. Environment index includes Noise Pollution and Exhaust Emission.

Noise Pollution. Traffic noise pollution degree is mainly affected by traffic flow, vehicle composition, traffic speed, road conditions, etc. So the VMS's guiding can affect it through affecting its factors.

Road network's noise function(μ_3):

$$\mu_3 = \sum_{i=1}^{I} \alpha_i \times L_{eqi} \tag{6}$$

In where, L_{eqi} represents section i 's equivalent A-weighted sound pressure level.

Exhaust Emission (Include CO, HC, NO). Drivers can not only reduce the fule consumption, but also reduce the exhaust emission under the VMS's guiding. So exhaust emission is another important index, this paper mainly focuses on three gases: CO, HC, and NO.

The quadratic polynomial fitting result between speed and exhaust emission and their related parameters are showed as follows:

$$y_{CO} = 0.0113x^2 - 1.7768x + 81.57 \quad R^2 = 0.9532 \tag{7}$$

$$y_{HC} = 0.0009x^2 - 0.1527x + 9.03 \quad R^2 = 0.9871 \tag{8}$$

$$y_{NO} = 0.025x + 2.8 \quad R^2 = 0.9871 \tag{9}$$

The road network's exhaust emission is the sum of every section's exhaust emission; it can be calculated as follows:

$$S_{Gas} = \sum_{i=1}^{I} L_i \times \beta_{Gas} \times Q_i \qquad Gas = CO、HC、NO \tag{10}$$

Safety. The urban congestion can be improved under the VMS's guiding, as a result, the distribution of road network's traffic flow tend to be more reasonable and drivers' lane changing behavior is reduced. So the rate of the traffic accidents will be reduced. The road's safety can be improved. This paper provide two methods to evaluate road's safety under two opposite conditions: having or not having accident data.

(1) Having accident data

When having accident data, the following four indexes can be chose to evaluate the safety, they are mortality rate per million vehicle kilometer (K_1), ponderance index of accident (K_2),mortality rate per ten thousand vehicles (K_3), equivalent accident number per ten thousand vehicles (K_4) [5]. Section i 's each index can be calculated by equation (11) to equation (15).

$$k_{1i} = \frac{F_i}{Q_i L_i} \times 10^8 \tag{11}$$

$$k_{2i} = \frac{F_i}{J_i} \tag{12}$$

$$k_{3i} = \frac{F_i}{Q_i} \times 10^4 \tag{13}$$

$$k_{4i} = \frac{(ETAN)_i}{Q_i} \times 10^4 \tag{14}$$

$$(ETAN)_i = (TAN)_i + 9.5F_i + 3.5J_i \tag{15}$$

In equation (15), F_i represents section i 's accident death toll (Unit: person); $(ETAN)_i$ represents section i 's the total number of equivalent accident (Unit: time). $(TAN)_i$ represents section i 's the number of accident (Unit: time). J_i represents section i 's wounded number in the accident (Unit: person).

Road network's each safety index can be calculated as follows:

$$K_a = \sum_{i=1}^{I} \alpha_i \times k_{ai} \qquad a = 1,2,3,4 \tag{16}$$

(2) Not having accident data

When not having accident data, this paper quotes Canada's urban and rural two-lane road survey analysis results: there is following relationship among the section i 's average speed, velocity difference and the rate of casualty (h_i):

$$h_i = 0.01802V_{85i} + 0.01884V_{di} - 1.94294 \quad R^2 = 0.95984 \tag{17}$$

In where, V_{85i} and V_{15i} separately represents the section i 's summation curve at 85% point speed and 15% point speed; V_{di} represents section i 's velocity difference, namely $V_{di} = V_{85i} - V_{15i}$ [6].

Driver. Driver index includes VMS Utilization Ratio and Drivers' Anxiety.

VMS Utilization Ratio. The VMS's guiding result can be evaluated from the view of drivers, if the VMS utilization ratio is big, then VMS play a part in guiding driving route. Under the reasonable guiding information, the bigger VMS utilization ratio, the better guiding result.

Drivers' Anxiety. Traffic congestion not only causes economic losses and environmental damage, but also makes drivers produce irritating mood. The VMS's guiding information let drivers understand surrounding condition, which can increase their controllability and decrease the anxiety. Thus, drivers' anxiety can be one of the indexes to evaluate the VMS's guiding result.

3 Comprehensive Evaluation Method of VMS's Guiding Result

Because there is no comprehensive evaluation methods completely match to VMS's guiding result evaluation. Thus, this paper compare different methods which are used

for ITS's evaluation and chose a better one. There are three factors for choosing: 1) considering evaluation index of VMS's guiding result; 2) considering the number of evaluation object; 3) considering evaluation result. Based on considering three factors above, the Grey relational analysis is chose.

The Grey relational analysis judge the connection's tightness according to the similarity of sequence curve's geometric shape, the tighter the curve close, the bigger the correlation among corresponding sequence is, the smaller the vice is. The evaluation includes 6 steps and each step's detailed content is as follows:

Step1: Ensure the analysis sequence. For this paper use the method of comparison between before and after, thus the number of evaluation is 2, and the number of evaluation index of each evaluation object is decided by decision maker, here assume n indexes and the original array matrix is as follows:

$$X\left[x_{i1}, x_{i2}, \ldots x_{in}\right] \qquad i = 1, 2 \tag{18}$$

Step2: The original data's dimensionless processing. In order to facilitate analysis and guarantee the indexes' equivalent, the original data should be handled with dimensionless and normalization.

Step3: Calculate maximum differential and minimum differential.

$$\Delta(\max) = \max_i \max_j (\left|x_{ij}' - 1\right|) \qquad i = 1, 2;\ j = 1, 2, \ldots, n \tag{19}$$

$$\Delta(\min) = \min_i \min_j (\left|x_{ij}' - 1\right|) \qquad i = 1, 2;\ j = 1, 2, \ldots, n \tag{20}$$

Step4: Calculate relational coefficient. Input the step 3's result into equation (21) to calculate relational coefficient.

$$\xi_{ij} = \frac{\Delta(\min) + \beta\Delta(\max)}{\Delta_{ij} + \beta\Delta(\max)} \qquad i = 1, 2;\ j = 1, 2, \ldots, n \tag{21}$$

In where, ξ_{ij} represents the relational coefficient of the i th evaluation object's j th index with the j th optimal index value in the optimal index muster. β ($0 < \beta < 1$) represents the differentiated coefficient. The value of β is 0.5.

Step5: Chose the reasonable method to calculate the weight according to practical condition. This paper chose AHP to calculate the weight.

Step6. Calculate relational coefficient according to equation (22).

$$E_i = \sum_{j=1}^{n} \omega_j \xi_{ij} \qquad i = 1, 2 \tag{22}$$

Obviously, the bigger value of E_i, the better VMS's guiding [7].

4 Example

This paper evaluates the VMS's planning project from the view of its guiding result. Take one area of Beijing's network for an example, VMS's layout is showed by Figure1.

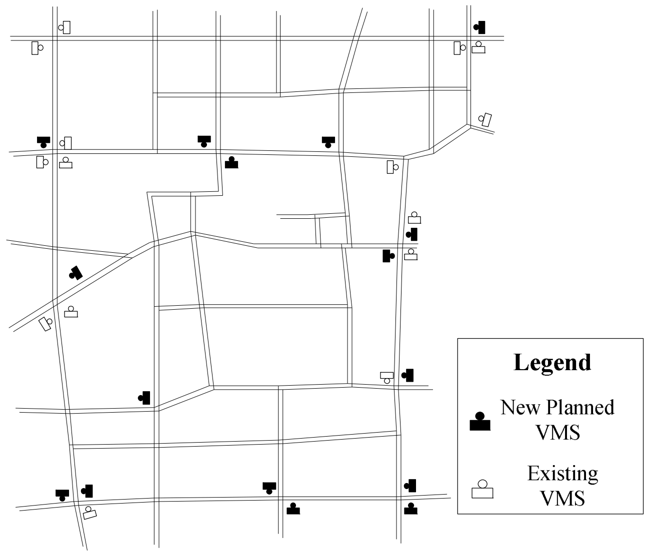

Fig. 1. The map of VMS layout in the planning project

Because of limited collected data, only 10 second-class indexes are calculated. The calculation result is showed by Table 2 and the results can be used to evaluate VMS's guiding result from single view; Based on calculation result, AHP is used to calculate the index's weight and Grey Relational Analysis is used to give a final evaluation to VMS. The comprehensive evaluation result is showed by Table 3. The relational coefficient increases from 0.952 to 0.999 because of building up VMS, namely, road network's condition is improved about 5%.

Table 2. The calculation result of evaluation indexes of VMS's induct result

First-Class Index	Second-Class Index	Before VMS	After VMS
Network	V/C Ratio	0.548	0.536
	Average Speed (km/h)	51.2	53.7
Economic	Time Saving (Yuan/h)	119835	106279
	Fule Consumption (Yuan/h)	44930	43842
Environment	Noise Pollution (DB)	77.1	77.2
	Co Emission (kg/h)	5569	4720
	HC Emission (kg/h)	929	839
	No Emission (kg/h)	974	975
Safety	Injuries and Deaths Ratio	2.7	2.9
Driver	Drivers' Anxiety (0-100)	68	52

Table 3. The calculation result of evaluation indexes of VMS's induct result

First-Class Index	Second-Class Index	Before VMS	After VMS	Changed Value	Changed Rate
Network	V/C Ratio	0.446	0.456	0.01	2.25%
Network	Average Speed (km/h)	0.088	0.092	0.004	4.93%
Economic	Time Saving (Yuan/h)	0.14	0.158	0.018	12.74%
Economic	Fule Consumption (Yuan/h)	0.052	0.053	0.001	2.46%
Environment	Noise Pollution (DB)	0.075	0.075	0	-0.20%
Environment	Co Emission (kg/h)	0.008	0.009	0.001	18.06%
Environment	HC Emission (kg/h)	0.065	0.072	0.007	10.74%
Environment	No Emission (kg/h)	0.016	0.016	0	-0.10%
Safety	Injuries and Deaths Ratio	0.035	0.032	-0.003	-7.70%
Driver	Drivers' Anxiety (0-100)	0.028	0.036	0.008	30.72%
Comprehensive Evaluation		0.952	0.999	0.047	4.98%

5 Conclusion

This paper build up evaluation index system of VMS's guiding result and the system is made up of network, economic, environment, safety and driver. The Grey relational Analysis is used to give out a comprehensive evaluation of VMS. The mainly research achievement is as follows: (1) Build up an evaluation system which is suitable for evaluating VMS's guiding result. (2) Take Beijing for an example and put the evaluation theory into practice.

Henceforth, the mainly research content will be carried out is to develop an evaluating software of VMS's guiding result.

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